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REMOVAL OF EMULSIFIED OIL AND AFFF USING AIR-SPARGED HYDROCYCLONE TECHNOLOGY

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ABSTRACT:

A range of Air Force (AF) activities generate wastewater containing suspended solids, oily substances, emulsion stabilizing agents, and aqueous, film-forming foam (AFFF) liquids. In a 1995 Small Business Innovative Research (SBIR) solicitation, the US Air Force was searching for a cost-effective method to handle this problem. This solicitation addressed two issues: (1) removal of emulsified oil, fuel, and grease from aircraft wash rack wastewater containing detergents and (2) removal of AFFF from firefighting wastewater.

A cooperative effort between AFRL/MLQ and Advanced Processing Technologies, Inc. (APT) has led to the development of Air-Sparged Hydrocyclone (ASH) technology. An ASH reactor can provide efficient removal of any hydrophobic particle in an aqueous waste stream. This includes emulsified petroleum, oil, and lubricant (POL) products. AFFF is removed via adsorption to hydrophobic particles. This technology can provide 80-100% removal of these contaminants from vehicle maintenance, vehicle wash rack, aircraft wash rack, jet engine test cell, and firefighting training pit waste streams.

The continuing SBIR Phase II work emphasizes on-site, pilot-scale tests with a trailer-mounted, mobile ASH unit modified from lessons learned during Phase I testing. The system has toured five different Air Force bases (AFB) and demonstrated its capability with various wastewater streams. The results of the demonstrations have confirmed that ASH technology is capable of effectively removing oil and grease, oily solids, and AFFF from these streams at low cost. Emulsified O&G and AFFF wastewaters can be treated for approximately \$0.40-1.10 per 1,000 gallons. The contracted effort will be completed by 1 Aug 98. Installations of ASH units are being

planned for 325 CES/CEV and AFRL/MLQC, Tyndall AFB, Fla. and 17 CES/CEV, Goodfellow AFB, Texas.

INTRODUCTION:

A range of AF activities generate wastewater containing suspended solids, POL products, emulsion stabilizing agents, and AFFF liquids. These contaminants may pose a nuisance to federal or civilian industrial wastewater treatment plant (IWTP) operations or actually force the effluent stream to be out of compliance with local discharge limits. These concerns have been identified as Environment, Safety, and Occupational Health (ESOH) Needs #912, "New Treatment Technologies for Removing Low-Level Emulsified Oils in Contaminated Wastewater from Point and Non-Point Sources (High Priority)," #1414, "Pollution Controls for Aircraft Wash Racks (High Priority)," and #1609, "Methods to Mitigate Problems Associated with the Release of AFFF From the Flooding of Hangars as a Fire Suppressant (Low Priority)."[1] More information on these needs and the entire ESOH needs process can be found at the USAF Human Systems Center Environmental Planning Directorate's (HSC/XRE) Environment, Safety, and Occupational Health Technical Planning Integrated Product Team (ESOH TPIPT) website.

Conventional wastewater pre-treatment processes are either ineffective or too costly to treat emulsified oils caused by the use of soaps and detergents and AFFF releases. Gravity oil/water (O/W) separators are not able to separate the chemically stabilized o/w emulsions that exit from aircraft and vehicle wash racks. Separators incorporating coalescing media provide only a marginal improvement in separation efficiency.[2] Other pre-treatment unit operations such as thermal treatment, chemical demulsification, depth filtration, and combinations thereof, are capital intensive and usually have high operation and maintenance costs. Wastewaters containing AFFF need pre-treatment before being released to federally or privately owned treatment works (FOTW, POTW) due to its persistent foaming and high biochemical oxygen demand (BOD). Biological degradation may be economically successful if containment facilities and aeration equipment are available; otherwise, large capital expenditures are necessary. Also, long residence time, sludge removal, and intermittent flow may be barriers to an effective biodegradation process.

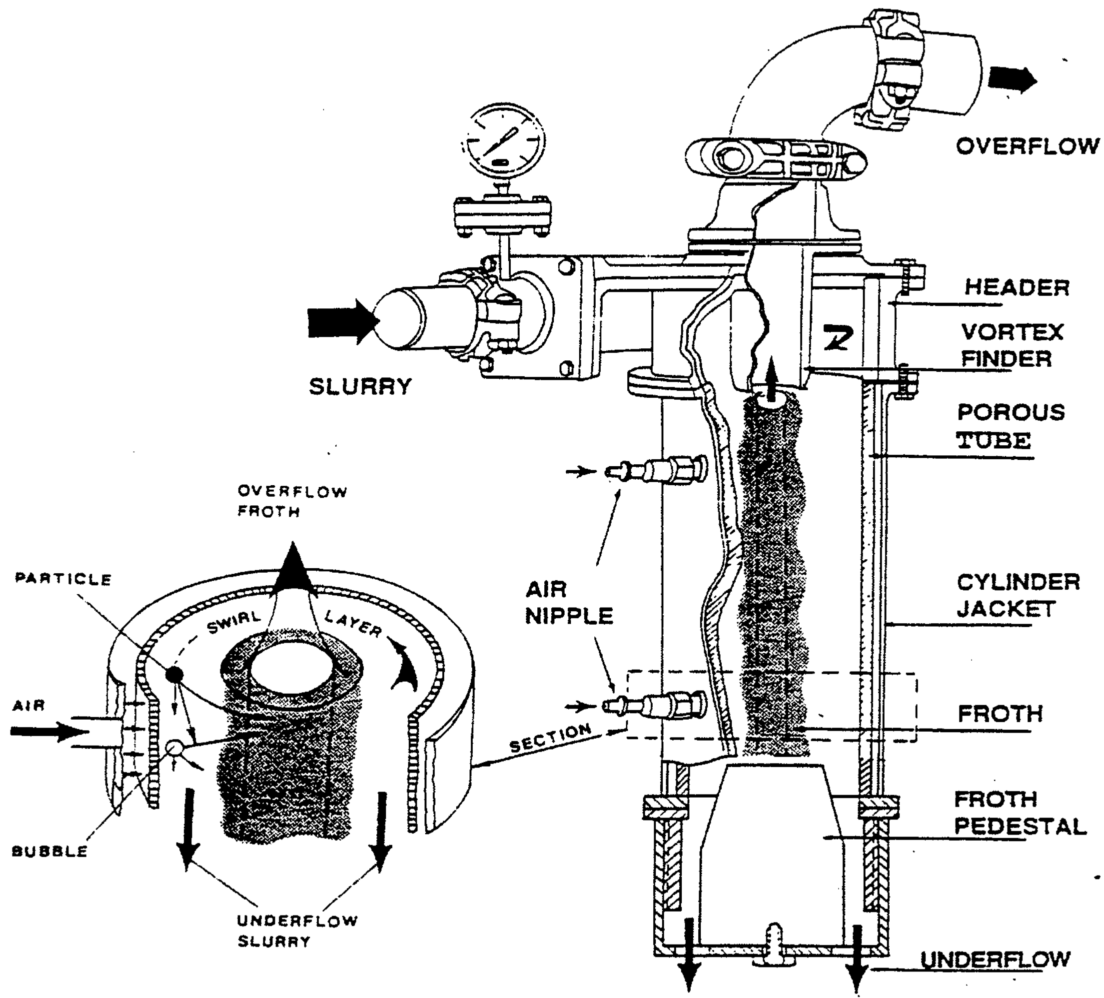
DISCUSSION:

AIR-SPARGED HYDROCYCLONE OPERATION

The air-sparged hydrocyclone unit removes hydrophobic solid particles or liquid droplets, including chemically emulsified oils, from wastewater. It consists of a jacketed, right-vertical, porous tube, a conventional cyclone header with a mounted vortex finder, and a froth pedestal/underflow structure that is centered on the cyclone axis at the bottom of the porous tube. See Figure 1. Wastewater is fed tangentially through the cyclone header to develop a swirl flow inside the porous tube. Pressurized air passes through the jacketed porous tube wall and is sheared into numerous fine bubbles by the high-velocity swirl flow of the suspension. Hydrophobic particles/oil droplets (or particles rendered hydrophobic by a chemical reagent) in the suspension collide with these bubbles, and, after bubble/particle attachment, are significantly reduced in their tangential velocity and transported radially into a froth phase which forms on the cylindrical axis. The froth phase is supported and constrained by the froth pedestal and thus moves towards the vortex finder of the cyclone header, being discharged as an overflow product. Cleaned water remains in swirl motion and is discharged as an underflow product through the annulus between the porous tube wall and the froth pedestal.

The design features of the ASH system improve the removal of fine particles in three ways. Firstly, a strong centrifugal force field is developed; the magnitude of the field is determined and controlled by the tangential velocity of the suspension and the cyclone diameter. This centrifugal force field results in increased inertia of fine particles and hence facilitates their collision and attachment to air bubbles. Secondly, the high-speed swirl flow exerts a considerable shear force at the porous tube inner surface wall. This, coupled with the fact that the air phase is introduced through extremely fine pores (35 - 140 microns), results in the generation of numerous fine air bubbles with average bubble diameter at about 100 microns. These small air bubbles are directed in the radial direction, orthogonal to the motion of particles contained in the swirl flowing water. As a result, the probability of collision of air bubbles with particles is significantly increased so that the collision event is no longer a rate determining process. Finally, the wastewater inside the ASH has two basic motions. One is the swirl motion along the circular inner surface of the porous tube, and another is an axial downward motion toward the bottom of the ASH. For a 2-inch inner diameter ASH 20 inches in length, any particular reference point in the influent wastewater may have approximately 9570 chances to collide with a freshly generated air bubble before it is discharged from the unit. It is these features that enable the ASH system to have a specific processing capacity (gallons processed per unit volume of the equipment) 100 - 500 times of any other conventional equipment. The ASH test unit used in all testing processed 20 gallons per minute (gpm). At that rate, each liter of wastewater resides in the ASH reactor (2.0-in. inside diameter, 24-in. long) for less than 0.25 seconds.

Figure 1. Schematic of the air-sparged hydrocyclone[3].



Designed And Manufactured By Advanced Processing Technologies, Inc.
Under Its Patent And Licenses From The University of Utah
US Patent 4,279,743 4,397,741 4,399,027 4,744,890 4,838,434 4,997,549 & Pending Applications

USAF SBIR PHASE II TEST RESULTS

At each test location, the wastewater for each test run was usually pulled from the o/w separator, floor sump, or containment structure that serviced the facility. Effluent characterization was determined from a one-liter grab sample collected adjacent to where the ASH feed pump was placed. The quality of the treated water was determined from a one-liter sample collected from the ASH discharge line after approximately ten minutes of operation. Independent laboratories conducted all chemical analyses, except AFFF concentrations, which were determined by APT. Quantitative values for total suspended solids (TSS), oil and grease (O&G), and total petroleum hydrocarbon (TPH) were obtained by EPA 160.2, EPA 413.1 or SM18 5520-B, and SW846 8015-M methodologies, respectively. Presently, there is no standard method to determine AFFF concentration in solution. APT developed two semi-quantitative methods to determine AFFF removal from firefighting training pit effluents: foam height (FH) and surface tension (ST) measurements. In the first method, air is passed through a specific volume of AFFF solution until the produced foam layer breaks and rises no higher. Surface tension measurements were made with a Kruss K10T Digital Ring Tensionometer. Calibration curves were produced for each method as a function of AFFF concentration. Measurements of the untreated and ASH treated solutions were plotted on the respective calibration curves to determine AFFF concentrations. The FH and ST calibration curves will not return an absolute AFFF concentration for a specific sample; however, they clearly bracket an estimation of AFFF removal

Tests were conducted at Tinker AFB, OK (24-25 Mar 97), Tyndall AFB, FL (3 Apr 97), Eglin AFB, FL (5 Apr 97), and Goodfellow AFB, TX (19-22 Nov 97). The results of these tests are in Table 4[6]. Aircraft wash rack effluents (ACWR) tested at Tyndall AFB were obtained from the primary chamber of the servicing O/W separator. The AFFF contaminated effluents from firefighting training exercises at Tyndall AFB are collected in a lined lagoon after passing through an O/W separator used to reclaim free phase fuel. The fire training pit (FTP) lagoon water, which is presently being treated by an aerobic biological process to reduce TPH and BOD, is used as make-up water for the fire pits or metered into the sanitary sewer. This lagoon water was used in the ASH test. At Goodfellow AFB, FTP effluents are gravity fed to a lift station where they are pumped to a 500,000-gallon holding tank without any treatment. Water from the bottom of the tank is metered to the sanitary sewer, used for fire pit make-up water, or reutilized in the firefighting pump trucks. Water for the Goodfellow test was taken from the lift station. The cost to treat Goodfellow AFB FTP wastewater was estimated to be $0.34-$0.44/1000 gal.

Table 1 ASH Treatment of Various AFB Waste Streams.

Stream	Test / Sample	Influent (ppm)	Effluent (ppm)	% Removal
Tyndall-FTP	TSS-1	53	4	93
	O&G-1	94	6	94
	AFFF(FH)-1	800	100	94
	AFFF(ST)-1	100	12	88
Eglin-VMF	O&G-1	5250	31	99
Goodfellow-FTP	TSS-1	390	3	99
	O&G-1	1850	6	99
	TPH-1	1120	ND	100
	AFFF-1			80-90

* ND – Non Detect

SUMMARY/CONCLUSIONS:

Through extensive testing on AF waste streams containing suspended solids, emulsified fuels and oils, metals, and AFFF liquids, air-sparged hydrocyclone technology has provided a high level of contaminant removal at very low cost. With the construction flexibility of fixed or mobile configurations, ASH technology could be utilized in a wide variety of AF applications. System attributes such as low capital cost, operation and maintenance expenses of only $0.40-$1.10/1000 gal, high throughput, process flexibility, and high contaminant removal rates, make the ASH an unbeatable value when designing wastewater treatment processes for AF waste streams. At the present time, a mobile ASH treatment system is being constructed for the 325 CES Environmental Flight, Tyndall AFB, Florida. In addition, a fixed ASH system is being constructed for AFRL/MLQC (Airbase Technology Development Branch) for installation at the 823 Civil Engineering Red Horse – Detachment 1, Silver Flag Fire Training Facility, Tyndall AFB, Florida. Also, a large, fixed ASH system is being considered for installation at the DoD Firefighting Training School, Goodfellow AFB, Texas.

REFERENCES:

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2. Acurex Environmental Corp., Draft report, "Testing of New Technologies for Oil/Water Separation at Dover AFB," USAF Contract # F0863-95-D6003/DO5302, December 1997.
3. Figure 1 schematic provided by Advanced Processing Technologies, Inc.
4. Advanced Processing Technologies, Inc., Third Quarterly Progress Report, USAF SBIR Phase II Contract F41624-96-C0003, 17 Feb 97.
5. Ibid.
6. Advanced Processing Technologies, Inc., Sixth Quarterly Progress Report, USAF SBIR Phase II Contract F41624-96-C0003, 28 Dec 97.
7. Ibid.